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# RF Voltage Requirements for a $f$ = 196 MHz RF System

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A study was done to find the required RF voltage and the performance of higher frequency RF systems with $f \simeq 196$ MHz. The study found that the required RF voltage at $f = 196$ MHz, to give acceptable beam losses, is $V = 6.6$ MV if the initial emittance is blown up to 60 $\pi$mm·mrad. If the initial emittance is 10 $\pi$mm·mrad, the required RF voltage is $V = 14$ MV. The required RF voltage was found to vary as the square of the RF frequency.

The present RF system has $f = 160$ MHz, $h = 2052$, $V = 4.5$ MV. Due to intrabeam scattering this system has losses from the RF bucket of the order of 17% for Au ions at $\gamma = 100$ over ten hours. A study was done of the intrabeam scattering effects at higher frequencies, $f \simeq 196$. This study was first done using the intrabeam scattering theory with no boundaries. The RF voltage required was determined by requiring the ratio of the bucket height, $\Delta_B$, to the rms energy spread, $\sigma_p$ to be $\Delta_B/\sigma_p \approx 4.8$ at $t = 0$, and $\Delta_B/\sigma_p = 1.8$ at $t = 10$ hours, which are the values found for $\Delta_B/\sigma_p$ for the $f = 160$ MHz system with $V = 4.5$ MV. These requirements on $\Delta_B/\sigma_p$ may be expected to give acceptable beam losses from the RF bucket. In the study, for each RF frequency, the RF voltage is varied to find the RF voltage that gave the above required values of $\Delta_B/\sigma_p$. The results of this study are given in the following table. The RF voltage is assumed to be held constant at its maximum value as the bunch grows. The results in the table are for Au ions at $\gamma = 100$ with $1 \times 10^9$ ions/bunch. The initial emittance is assumed to be blown up to 60 $\pi$mm·mrad.

| | | | | |
|---|---|---|---|---|
| | $f$ (MHz) | 160 | 187 | 196 |
| | $h$ | 2052 | 2394 | 2508 |
| | $V$ (MV) | 4.5 | 6.0 | 6.6 |
| t=0 | | | | |
| | $\sigma_p/10^{-3}$ | 0.411 | 0.460 | 0.476 |
| | $\sigma_\ell$ (cms) | 12 | 11 | 10.7 |
| | $\epsilon_x$ $\pi$ mm·mrad | 60 | 60 | 60 |
| | $\Delta_B/\sigma_p$ | 4.8 | 4.6 | 4.5 |
| t=10 hours | | | | |
| | $\sigma_p/10^{-3}$ | 1.11 | 1.19 | 1.21 |
| | $\sigma_\ell$ (cms) | 34 | 29 | 27.1 |
| | $\epsilon_x$ $\pi$ mm·mrad | 70 | 72 | 72 |
| | $\Delta_B/\sigma_p$ | 1.8 | 1.8 | 1.8 |

The above results show that the RF voltage required goes as the square of the RF frequency. For $f = 196$ MHz, $h = 2508 = 114 \times 22$, $V = 6.6$ MV is required.

The result for $f = 200$, was checked by computing the losses from the RF bucket due to intrabeam scattering. Losses of about 15% were found for $V = 7$ MV.

The $\sigma_\ell$ is smaller for $f = 196$ MHz with $\sigma_\ell \leq 19$ cms for $f = 196$ compared to $\sigma_\ell \leq 24$ cms for $f = 160$ MHz. There is a small increase in $\sigma_p$ and $\epsilon_x$ for $f = 196$. The inclusion of the losses from the RF bucket reduces the results for $\sigma_\ell$ and $\sigma_p$ given in the above table by about 30%, and the results after 10 hours are $\sigma_p = 0.777 \times 10^{-3}$, $\sigma_\ell = 24$ cms for $f = 160$ and $\sigma_p = 0.847 \times 10^{-3}$, $\sigma_\ell = 19$ cms for $f = 196$.

The above results were derived assuming the initial emittance, $\epsilon_x$, is blown up to 60 $\pi$mm·mrad to reduce the required RF voltage. Blowing up the beam to $\epsilon_x = 60$ reduces the luminosity by about a factor of 3 and increases the required transverse aperture. It is interesting to ask what RF voltage would be required if the initial emittance is not blown up but kept at $\epsilon_x = 10$. The required RF voltage for $\epsilon_x = 10$ was found to be $V = 14$ MV. This voltage gives $\Delta_B/\sigma_p = 5.5$ at $t = 0$, and $\Delta_B/\sigma_p = 1.8$ at $t = 10$ h, and may be expected to give acceptable beam losses of the order of 15%. For $f = 196$, $V = 14$ MV,

$\epsilon_x = 10$, the final parameters after 10 hours are $\epsilon_x = 38$, $\sigma_p = 1.25 \times 10^{-3}$ and $\sigma_\ell = 19$ cms.

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